SYSTEM AND METHOD FOR A ROBUST PREAMBLE AND TRANSMISSION DELIMITING IN A SWITCHED-CARRIER TRANSCEIVER

CROSS-REFERENCE TO RELATED APPLICATIONS

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This document claims priority to, and the benefit of, the filing date of Provisional Application Serial No. 60/150,436 entitled "A TECHNIQUE FOR ROBUST SIGNAL DELIMITING AND ENCODING OF CRITICAL LINK CONTROL SIGNALS APPLIED TO TRANSMISSION OF ATM CELLS OVER A DSL USING ADAPTIVE TIME DOMAIN DUPLEX (ATDD)," filed on August 24, 1999, (Attorney Docket No.

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61606-8170; 1999-06), which is hereby incorporated by reference.

TECHNICAL FIELD

The present invention relates generally to communications systems, and more

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particularly, to a system and method for a robust preamble and transmission delimiting in a switched-carrier transceiver.

BACKGROUND OF THE INVENTION

Data communication typically occurs as the transfer of information from one

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communication device to another. This is typically accomplished by the use of a modem located at each communication endpoint. In the past, the term modem denoted a piece of communication apparatus that performed a modulation and demodulation function, hence the term "modem". Today, the term modem is typically used to denote any piece of communication apparatus that enables the transfer of data and voice information from one

location to another. For example, modern communication systems use many different

technologies to perform the transfer of information from one location to another. Digital

subscriber line (DSL) technology is one vehicle for such transfer of information. DSL

technology uses the widely available subscriber loop, the copper wire pair that extends

5   from a telephone company central office to a residential location, over which

communication services, including the exchange of voice and data, may be provisioned.

DSL devices can be referred to as modems, or, more accurately, transceivers, which

connect the telephone company central office to the user, or remote location typically,

referred to as the customer premises. DSL communication devices utilize different types

10   of modulation schemes and achieve widely varying communication rates. However, even

the slowest DSL communications devices achieve data rates far in excess of conventional

point-to-point modems.

DSL transceivers can be used to provision a variety of communication services

using, for example, asynchronous transfer mode (ATM). ATM defines a communication

15   protocol in which 53 octet (byte) cells are used to carry information over the DSL

communication channel. The first five octets of the ATM cell are typically used for

overhead and the remaining 48 octets are used to carry payload data. When using a

switched-carrier transmission methodology, a control transceiver may be connected via

the DSL to one or more remote transceivers. In such a communication scheme, the

20   transmission is commonly referred to as "half-duplex," which is defined as two way

electronic communication that takes place in only one direction at a time. With only a

single remote transceiver on a line, switched-carrier transmission may instead be

employed in full-duplex mode (*i. e.,* allowing transmission in both directions

simultaneously). In this case, full-duplex operation is typically enabled by employing

either echo cancellation or frequency division multiplexing. Hybrid techniques are

possible such as one in which there are multiple remote transceivers and communication

takes place between the control transceiver and only one remote transceiver in full-duplex

5   fashion. As it relates to the present invention, the common characteristic of these

communication techniques is the use of a switched-carrier modulation in which

transmitters are deliberately silent for some interval between signal transmissions. For

simplicity, the following discussions assume the simplest case of using switch carrier

modulation with a half-duplex (also sometimes referred to as "time domain duplex") line

10   usage discipline.

Before the transmission of ATM cells, a preamble containing channel,

transmission, address and administrative information may be transmitted by the

transceiver. The application of this preamble is sometimes referred to as "framing" the

data to be transmitted. Due to the switched-carrier nature of the transmission, silence

15   precedes this preamble and it is of course important for all symbols in this preamble to be

received error free. It is also desirable to have the ability to precisely delimit the

beginning and end of a transmission to within one transmitted symbol interval. Robustly

delimiting the beginning of a message enables a receiving transceiver to reliably begin

immediately decoding the message at the correct symbol. Likewise, robustly delimiting

20   the end of a message enables a receiving transceiver to reliably decode the entire message

through the final symbol and then stopping so as to prevent data loss and to prevent the

inclusion of any false data. Furthermore, by communicating the end of message indicator

to a receiving transceiver prior to the actual end of the message, line turnaround time (*i.e.*,

idle time on the line between transmissions) can be reduced, thereby increasing the effective use of the available line bandwidth.

Because the most efficient signal constellation encoding cannot allocate signal space to silence, it is impractical to reliably discriminate silence from a signal when analyzing only a single symbol encoding an arbitrary data value.

To improve message delimiting, existing techniques use special marker symbols whose symbol indices are greater than those used to encode data. At N bits per symbol (bps) data is encoded using symbol indices 0 through 2^N-1. The special symbols use indices 2^N and above. While these special marker symbols are useful for marking the beginning and end of a transmission, their placement at the outer edges of a constellation raises the peak signal, thus increasing the peak to average ratio (PAR) across all data rates by as much as 4dB. Unfortunately, discrimination of special symbols has the same error threshold as does decoding of data.

Thus, it would be desirable to have a robust manner in which to detect the beginning and end of a transmission so that line bandwidth can be most efficiently allocated. Furthermore, it would be desirable to robustly transmit a message preamble including control information thereby greatly improving the probability that the preamble is received error free.

SUMMARY OF THE INVENTION

The present invention provides an improved system and method for robustly delimiting a message transmission in switched-carrier communication systems. The invention provides a method and system for transmission of a message preamble in which

transmission of the preamble is more robust than the data. In this manner, the beginning and end of a transmission can be robustly delimited and channel control information can be reliably conveyed to a receiving transceiver.

The system of the present invention uses a novel header application, which

5   enables the transport of ATM, or any other data, efficiently and economically over a communications channel, such as a DSL communications channel.

Briefly described, in architecture, the system for robust transmission delimiting comprises a communication message including a preamble including a plurality of bits representing communication link control information, and an encoder configured to

10   encode the preamble bits into a plurality of symbol indices. The symbol indices are encoded at a lower bit per symbol rate relative to the maximum rate capable of being supported over a communication channel.

In another aspect, the invention is a system for delimiting the end of a transmission. The system takes a communication message segmented into a plurality of

15   fixed size units, each fixed size unit including a plurality of bits, and includes an encoder configured to encode the plurality of bits into a plurality of symbol indices at a first data rate. The encoder is also configured to encode the first symbol index containing only bits from each fixed size unit at a data rate lower than that of the first data rate.

The present invention can also be viewed as a method for robust transmission

20   delimiting comprising the steps of applying a preamble to a communication message, the preamble including a plurality of bits representing communication link control information, and encoding the preamble bits into a plurality of symbol indices. The

symbol indices are encoded at a lower bit per symbol rate relative to the maximum rate capable of being transmitted over a communication channel.

In another aspect, the invention is a method for delimiting the end of a transmission comprising the steps of segmenting a communication message into a plurality of fixed size units, each unit including a plurality of bits, encoding a plurality of the bits in the cells into a plurality of symbol indices, the symbol indices being encoded at a first rate, and encoding the first symbol index containing only bits from each fixed size unit at a rate lower than that of the first rate.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. 1 is a schematic view illustrating a switched-carrier half-duplex communication environment, in which DSL transceivers containing the present invention reside;

FIB 2A is an illustration of the time-domain duplex communication methodology employed by the DSL transceivers of FIG. 1;

FIG 2B is a schematic view illustrating, in further detail, a communication message of FIG. 2A;

FIG. 3A is a schematic view illustrating the bit to symbol relationship of the communication message of FIG. 2B;

FIG. 3B is a schematic view illustrating, in further detail, the preamble of FIG. 3A;

5   FIG. 4A is a graphical illustration representing a two (2) bit per symbol signal space constellation and the increased energy symbol of FIG. 3B;

FIG. 4B is a graphical illustration showing an exemplar grouping of constellation points representing different bit per symbol rates in accordance with an aspect of the invention;

10   FIG. 5 is a schematic view illustrating the communication message of FIG. 3A and a technique for scrambling that further improves reliable transmission of the message preamble;

FIG. 6 is a schematic view illustrating the communication message of FIG. 3A and the reduced line turn around delay made possible by an aspect of the invention;

15   FIG. 7 is a block diagram illustrating the control DSL transceiver of FIG. 1;

FIG. 8 is a block diagram illustrating the encoder of FIG. 7; and

FIG. 9 is a block diagram illustrating the decoder of FIG. 7.

DETAILED DESCRIPTION OF THE INVENTION

20   Although, described with particular reference to the transmission of ATM cells over a DSL communication channel, the system and method for a robust preamble and transmission delimiting can be implemented to transmit all forms of data in any switched-

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carrier transmission system in which it is desirable to send a robust preamble and to robustly delimit the beginning and end of each communication message.

Furthermore, the system and method for a robust preamble and transmission delimiting can be implemented in software, hardware, or a combination thereof. In a preferred embodiment(s), selected portions of the system and method for a robust preamble and transmission delimiting are implemented in hardware and software. The hardware portion of the invention can be implemented using specialized hardware logic. The software portion can be stored in a memory and be executed by a suitable instruction execution system (microprocessor). The hardware implementation of the system and method for a robust preamble and transmission delimiting can include any or a combination of the following technologies, which are all well known in the art: an discrete logic circuit(s) having logic gates for implementing logic functions upon data signals, an application specific integrated circuit having appropriate logic gates, a programmable gate array(s) (PGA), a field programmable gate array (FPGA), *etc*

Furthermore, the robust preamble and transmission delimiting software, which comprises an ordered listing of executable instructions for implementing logical functions, can be embodied in any computer-readable medium. Moreover, use by or in connection with an instruction execution system, apparatus, or device, such as a computer-based system, processor-containing system, or other system that can fetch the instructions from the instruction execution system, apparatus, or device and execute the instructions.

In the context of this document, a "computer-readable medium" can be any means that can contain, store, communicate, propagate, or transport the program for use by or in

connection with the instruction execution system, apparatus, or device. The computer

readable medium can be, for example but not limited to, an electronic, magnetic, optical,

electromagnetic, infrared, or semiconductor system, apparatus, device, or propagation

medium. More specific examples (a non-exhaustive list) of the computer-readable

5   medium would include the following: a electrical connection (electronic) having one or

more wires, a portable computer diskette (magnetic), a random access memory (RAM), a

read-only memory (ROM), an erasable programmable read-only memory (EPROM or

Flash memory) (magnetic), an optical fiber (optical), and a portable compact disc read-

only memory (CDROM) (optical). Note that the computer-readable medium could even

10   be paper or another suitable medium upon which the program is printed. As the program

can be electronically captured, via for instance optical scanning of the paper or other

medium, then compiled, interpreted or otherwise processed in a suitable manner if

necessary, and then stored in a computer memory.

Turning now to the drawings, FIG. 1 is a schematic view illustrating a switched-

15   carrier half-duplex communication environment 11, in which DSL transceivers

containing the present invention reside. Although the invention will be described below

in a half-duplex communication environment, the DSL transceivers containing the

invention may be used in a switched-carrier full-duplex environment as well. In such a

case, full-duplex operation may be enabled using technologies such as echo cancellation

20   or frequency division multiplexing. Communication environment 11, includes central

office 12 connected via communication channel 16 to customer premises 21.

Communication channel 16 can be any physical medium over which communications

signals can be exchanged, and in the preferred embodiment, is the copper wire pair that

extends from a telephone company central office to an end-user location, such as a home

or office. Central office 12 includes DSL transceiver 100 connected to communication

channel 16. DSL transceiver 100 processes data via connection 14. DSL transceiver 100

exchanges data via connection 14 with any data terminal equipment (DTE), such as a

5   computer or data terminal.

Customer premises 21 includes one or more DSL transceivers 150 connected via

internal infrastructure wiring 18 to communication channel 16. The infrastructure wiring

18 can be, for example but not limited to, the telephone wiring within a private residence

or within an office. DSL transceivers 150 can be connected to a variety of

10   telecommunication devices located at customer premises 21. For example, DSL

transceiver 150 connects via connection 22 to a personal computer 26. Although

additional DSL transceivers can be located at customer premises 21, an exemplar one of

which is indicated using reference numeral 155, the aspects of the invention to be

discussed below are also applicable if only one DSL transceiver 150 is located at

15   customer premises 21. In the example given in FIG. 1, DSL transceiver 155 connects to

computer 28 via connection 29.

The DSL transceiver 100 located at central office 12 is considered a "control.

device" and the DSL transceiver 150 located at customer premises 21 is considered a

"remote device." This is so because the control DSL transceiver 100 controls the

20   communication sessions by periodically polling each remote DSL transceiver 150 to

determine whether the remote device has information to transmit. Regardless of the

number of DSL transceivers located at customer premises 21, the method of

communication between DSL transceiver 100 located at central office 12 and DSL

transceiver 150 located at customer premises 21 is half-duplex in nature, sometimes

referred to as adaptive time-domain duplex, or data driven half-duplex, unless the above-

mentioned technologies such as echo cancellation or frequency division multiplexing

allow full-duplex operation between the control transceiver 100 and one remote

5   transceiver 150. This means that during any time period only one DSL transceiver may

transmit at any time. In the situation in which there are multiple DSL transceivers located

at customer premises 21, the DSL transceiver 100 located at central office 12 periodically

polls each DSL transceiver located at customer premises 21 at an appropriate time to

determine whether any of the remotely located DSL transceivers have any information to

10   transmit to central office 12. If only one DSL transceiver 150 is located at customer

premises 21, the communication method may be half-duplex in nature or conventional

full-duplex techniques may be used (*e. g.*, using either frequency division multiplexing or

echo cancellation).

FIG. 2A is a schematic view illustrating the time-domain duplex communication

15   methodology between a control DSL transceiver 100 and a remote DSL transceiver 150.

When a control DSL transceiver 100 desires to send a message to a remote DSL

transceiver 150 the control DSL transceiver 100 sends a communication message 31

including a preamble and any information that is to be transmitted. There are times when

the communication message may include only a preamble. After the transmission of

20   communication message 31, the remote DSL transceiver to which communication

message 31 is addressed (in this example remote DSL transceiver 150) responds with

communication message 32. After the remote DSL transceiver 150 completes the

transmission of communication message 32, the control DSL transceiver 100 is now free

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to send another communication message 34 to either the same remote DSL transceiver

150 or, if present, a different remote DSL transceiver, such as DSL transceiver 155

(remote "n") of FIG. 1. As illustrated in FIG. 2A, remote DSL transceiver "n" responds

with communication message 36. In this manner, the communication methodology

5 between control DSL transceiver 100 and all remote DSL transceivers 150, 155... n, is

switched-carrier and time-domain duplexed.

FIG 2B is a schematic view illustrating, in further detail, the communication

message 31 of FIG. 2A. Communication message 31 begins with preamble 40 followed

by optional administrative header 42. In accordance with an aspect of the invention, all

10 communication messages, regardless of the content, begin with preamble 40.

Administrative header 42 is optional and can be used to send information that is neither

part of the preamble 40 or of any data to follow. For example, the administrative header

42 could convey a description of noise level conditions at one end so the other end may

opt to increase or reduce the power level of its transmission as necessary. Likewise, the

15 administrative header 42 sent by a remote transceiver could contain information regarding

the amount of payload information that the remote transceiver is ready to transmit and its

relative priorities so that the control transceiver could alter the amount of time that this

remote transceiver is given to transmit its data (relative to any other transceivers

connected to the line). When the payload data comprises ATM cells, the control

20 transceiver could use messages conveyed by the administrative header 42 to direct remote

devices to activate or deactivate various ATM virtual circuits.

If data is included in communication message 31, one or more ATM cells follow

the optional administrative header 42. Although illustrated using three ATM cells, 44, 45

and 46, there are situations in which no ATM cells, or for that matter, no information of any kind, follows preamble 40. In the case in which information does follow preamble 40, and for purposes of illustration only, ATM cells 44, 45 and 46 are each standard 53 octet ATM cells. For example, ATM cell 44 includes 5 octet ATM header 47 and 48

5   octets of ATM data 48. ATM cells 45 and 46 are identical in structure to ATM cell 44. ATM cells 44, 45 and 46 adhere to the conventional ATM cell structure as defined in standardized ATM literature. It should be noted that optional administrative header 42 does not follow the standard ATM cell format and that administrative header 42 can be any number of octets in length. As known to those having ordinary skill in the art, an

10   octet comprises 8 bits of information. Although described with particular reference to the transportation of ATM cells over a DSL communication channel, the principles of the invention are applicable to all fixed length communication messages.

FIG. 3A is a schematic view illustrating the bit to symbol relationship of the communication message 31 of FIG. 2B. In accordance with an aspect of the invention,

15   preamble 40 is placed at the beginning of every transmission (*i.e.*, each communication message 31). Preamble 40 is followed by optional administrative header 42, which is then followed, if there is data to transmit, by one or more 53 octet ATM cell 44 and 45. Although illustrated using only two ATM cells, any number of ATM cells may follow preamble 40 and, if included, optional administrative header 42. The ATM cells are a

20   stream of data information represented as a series of bits that are placed into each ATM cell.

The preamble 40 is also a series of bits, which are encoded into a number of communication symbols. Symbols are the representation of the bits to be transmitted, and

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are represented as signal points in a signal space constellation (to be described below with

respect to FIGS. 4A and 4B). In accordance with one aspect of the invention, each of the

bits in preamble 40 are encoded into symbols, an exemplar one of which is illustrated

using reference numeral 55, at the lowest available bit rate that can be transmitted over

5   the communication channel 16. For purposes of illustration only, the symbols that encode

the bits in the preamble 40 shown in FIG. 3A are encoded at a rate of two (2) bits per

symbol. However, any number of bits per symbol lower than that of the normally

transmitted data rate can be used so long as the symbol rate allows a receiving device to

more reliably decode those symbols. For example, if the normal data rate is five (5) bits

10   per symbol, then a symbol rate of two (2) bits per symbol has a significantly

(approximately 9 dB) higher noise margin than the five (5) bit per symbol data rate,

thereby allowing the symbols that are encoded at the lower rate of two (2) bits per symbol

to be very robustly and reliably decoded by a receiving device. In this manner, the

preamble 40, which is sent at the beginning of every communication message 31, can be

15   made sufficiently robust so that the chance that it will always be received error free is

greatly increased. Although very robust, there are still situations in which the symbols

into which the preamble bits are encoded can be corrupted. However, in accordance with

another aspect of the invention, because the preamble 40 is sent at the beginning of every

communication message 31, even if the preamble 40 is corrupted, only data following

20   that preamble may be affected, *i.e.*, lost due to corruption, if certain bits of the preamble

are corrupted.

In accordance with another aspect of the invention, the first symbol 55

representing the first bits in the preamble 40 can be sent using an increased power level,

thereby clearly and robustly delimiting the beginning of the communication message 31. The effect of this increased power level symbol 55 will be explained in greater detail below with respect to FIGS. 4A and 4B.

Still referring to FIG. 3A, if an administrative header 42 is present in communication message 31, then the bits that are contained in administrative header 42 will be encoded at a symbol rate of "N" bits per symbol, where N is the normal data rate. The normal data rate can be any data rate, for example, but not limited to, a value between 2 and 12 (inclusive) bits per symbol. For purposes of illustration, and for simplicity of explanation, the normal symbol rate can be five bits per symbol. This is represented by the group of symbols 56 into which all the bits of administrative header 42 and a portion of the bits of header 47 of ATM cell 44 are encoded.

In accordance with another aspect of the invention, the first symbol used to encode bits from a particular cell that contains bits only from that cell will be encoded at a data rate lower than that of the standard data rate used for all other bits of each cell. For example, symbol 57 is the first symbol that contains bits only from ATM cell 44. The last symbol 65 of symbol group 56 contains bits from both administrative header 42 and ATM cell 44. Likewise, symbol 60 is the first symbol containing only bits from ATM cell 45. In accordance with this aspect of the invention, the symbols 57 and 60 will be encoded at a data rate that is two (2) bits per symbol lower than that of the preceding symbol (represented by N-2 where N is the number of bits per symbol used for encoding all other bits of the administrative header and ATM cells.) In this manner, because of the fixed length 53 octet ATM cells, by simple bit counting, the receiver will always know the first symbol encoding bits from a cell that contains only bits from this cell, and

therefore has the special encoding described herein. These N-2 bits of the cell data are grouped for transmission and an additional bit (bit 54 for cell 44 or bit 61 for cell 45) is added for a total of N-1 bits encoded into symbol 57 or 60, respectively. This group of N-1 bits, represented by symbol 57 or 60, is encoded into a symbol and scaled for transmission with the scaling normally applied when encoding at N-1 bits per symbol. The extra bit 54 or 61 indicates whether or not the cell just started (ATM cell 44 or 45, respectively) is the last cell of the transmission. The extra bit 61 in symbol 60 is set to logic one to indicate that ATM cell 45 is the last cell of the transmission so that the receiver will know at the beginning of the receipt of ATM cell 45 that ATM cell 45 is the last cell in the transmission. For the same reason, bit 54 in symbol 57 set to zero so that the receiver will know that at least one more cell follows cell 44.

If N=2, then no bits are taken from the cell to encode the next symbol (since N-2=0). Since N-1=1, the next symbol contains just one bit, which is the last cell indicator. This effectively inserts an entire extra symbol in each cell. Nevertheless, the same encoding/decoding logic for this special symbol applies for any value of N ≥ 2.

Once the receiver knows that a particular cell is the last cell in the message, by simple counting it can readily identify the symbol that contains the last bits of the last cell. This is represented in FIG. 3A as symbol 51 or optionally symbol 53. Since the number of bits remaining to be transmitted in the last symbol (M) can be less than N, a modified encoding technique is preferable for this symbol. One option is to add one or more padding bits (P) 52 so that M+P=N. Another option is to encode the last group of bits at M bits per symbol as represented by symbol 53. This has the advantage of increased robustness for the transmission of these bits.

For simplicity, the following discussion does not address this second technique. Having recognized the last symbol of the transmission, the receiver does not attempt to demodulate and decode the signal on the line following this symbol since the transmitting station must now be sending silence.

It should be noted that although described as being encoded at N-1 bits per symbol, the symbols 57 and 60 containing the additional last cell indicator bit can be encoded at any symbol rate lower than that of the standard transmission rate (N bits per symbol). For example, if N is five (5), the specially encoded symbols could also be encoded at N-2 or three (3) bits per symbol so that they contain two (2) bits of cell data plus the last cell indicator bit. In this manner, the receiver can clearly and reliably decode the symbol 60, thereby providing a robust and reliable end of message delimiter.

In accordance with this aspect of the invention, and to be described in further detail with respect to FIG. 3B, it is also desirable to have the ability to indicate that a message contains only an administrative header 42. In order to accomplish this, the first symbol containing data from the administrative header 42 can also be encoded using the higher noise margin N-1 bit per symbol encoding technique described above. For example, the first N-2 bits of the administrative header 42 can be combined with a last cell bit (such as bit 61 of symbol 60) and be encoded at the N–1 bit per symbol rate. This can provide the extra bit to indicate whether or not one or more ATM cells follow administrative header 42. An alternative technique is to simply include a bit in the preamble 40 that indicates whether an administrative header 40 follows the preamble. For simplicity, it has been assumed that this alternative technique is used with respect to FIG. 3A and in the following discussion.

Because each ATM cell is the smallest unit of a payload of ATM cells, and because all ATM cells have the same length, the first symbol of each cell that carries only bits of that cell can readily be identified. Because these bits are transmitted using the specially encoded symbol carrying two fewer bits than normal (as described above), the length of each cell is effectively increased by two bits. In some cases this can result in one extra symbol being needed to transmit the cell. In other cases an additional cell is not needed because the spare bits are available anyway (and would have ended up as the padding bits (P) 52 in FIG. 3A). Because the cells may be transmitted contiguously as a bit stream, the addition of one extra symbol may provide sufficient extra bits to cover the opening symbol of multiple following cells. For example, at eight (8) bits per symbol, one (1) extra symbol is needed to cover the end of frame signaling overhead to transmit up to four (4) cells.

FIG. 3B is a schematic view illustrating, in further detail, the exemplar preamble 40 of FIG. 3A. The bit stream of preamble 40 comprises four (4) bits 62 that include information regarding the transmit rate (in bits per symbol) used to encode data following preamble 40 (the data comprising the optional administrative header and optional ATM cells), four (4) bits 63 that include information regarding the rate (also in bits per symbol) that the receiver is capable of receiving, two (2) bits 64 that identify the address of a remote DSL transceiver if the control DSL transceiver is transmitting (if a remote DSL transceiver is transmitting, then these two (2) bits 64 can represent the address of that remote DSL transceiver) and two (2) bits 66, which can be used to communicate the format of the message to follow. For example, the two (2) bits 66 can be used to advise a receiving device whether an administrative header 42 follows the preamble 40, whether

ATM cells follow the preamble, whether both follow or whether only the preamble is being transmitted. The four (4) bits provided by symbols 55 and 67 and by symbols 68 and 69 can each encode as many as sixteen data encoding rates.

As mentioned above, the preamble 40 is sent at the beginning of each transmission. The twelve (12) bits that comprise the preamble 40 are encoded into symbols 55, 67, 68, 69, 70 and 71 in accordance with that described above. In accordance with an aspect of the invention, all of the symbols in preamble 40 are encoded at a low bit per symbol rate. In this example, all of the symbols are encoded at a rate of two (2) bits per symbol, however, any other low bit per symbol rate can be used with similar results. The low bit per symbol rate ensures a high signal-to-noise ratio for these symbols, thereby significantly decreasing the probability that these preamble symbols will be corrupted by noise on the communication channel. The payload data (administrative header and ATM cells) would typically be encoded at N bits per symbol only if transmission at this N bit per symbol rate has an acceptably low rate of errors (based on line length, signal strength, noise, distortion and other impairments that may be present). Otherwise, data transmission efficiency would suffer. Therefore, encoding the preamble at less than N bits per symbol allows a corresponding improvement in the reliability of transmitting this information such that it is highly unlikely to be corrupted. Since very few bits are needed to convey the information carried in the preamble, a very low rate can be used without seriously reducing the overall transmission efficiency.

In accordance with another aspect of the invention, the first symbol 55 is encoded at a rate of two (2) bits per symbol and has its energy increased to a point at which noise on the communication channel is unlikely to cause a receiver to erroneously interpret the

first symbol 55 as silence. Likewise the increased energy makes it unlikely that noise on

the communication channel will cause the receiver to erroneously interpret an interval of

the silence that precedes each message as the starting symbol of a message. It has been

found that an energy increase of 3dB is sufficient. This aspect of the invention will be

5   described in greater detail below with respect to FIGS. 4A and 4B. In this manner, the

beginning of each transmission can be clearly and robustly delimited. The remainder of

the symbols 67, 68, 69, 70 and 71 that represent the bits in preamble 40 are all encoded at

two (2) bits per symbol, but do not have their energy increased.

The four (4) transmit rate bits 62 inform a receiving DSL transceiver of the

10   transmit rate of the information to follow the preamble 40. Sending this information in

every message has significant benefits. It provides the transmitting transceiver the option

of changing the encoding rate for the payload from one message to the next. Messages

containing information that has been determined to be of high priority can be transmitted

using a lower number of bits per symbol to improve the chances of its being received

15   without errors. If the communications system intermittently has a reduced throughput

demand, the transceivers may instantly reduce their data rates to improve robustness

without adversely affecting real throughput. Finally, if a severe noise condition (such as

an impulse caused by plain old telephone service (POTS) ringing signals on a subscriber

line 16) happens to corrupt one or both of the symbols 55 and 67 that encode the transmit

20   rate, only the payload data in this message will be improperly decoded. The receiver's

memory of a corrupted rate value lasts only until the next transmission begins. This

allows the transmit rate to potentially be changed for every message while at the same

time avoiding the complexities of providing fail-safe communication of the rate, such as

through use of an automatic repeat request (ARQ) protocol, that would be needed if the rate is sent only when it is changed.

The receive rate bits 63 allow the transmitting device to communicate to the receiving device the maximum receive rate at which the transmitting device can receive. Inherently included in these receive rate bits 63 are commands that instruct the opposite device to either increase or decrease its transmit rate. This allows the responding transceiver to instantly modify the rate it uses for its next transmission to accommodate changes in the signal quality that have been detected at the opposite end of the line.

In accordance with an aspect of the invention, the address bits 64 need only be used when the control DSL transceiver 100 is communicating with a plurality of remote DSL transceivers in what is commonly referred to as "multi-point" mode. When communicating in "multi-point," mode the address bits 64 include either the address of the remote DSL transceiver 150 that is to transmit next (if the transmission is sent by the control DSL transceiver 100) or the address of the responding remote DSL transceiver 150 (if the transmission is sent by the remote DSL transceiver 150). Sending these bits 64 at the lower bit rate of the preamble reduces the likelihood of a remote transceiver 150 not responding or of the incorrect remote transceiver 150 responding to a message from the control transceiver 100. Frequent occurrence of either of these two types of errors could adversely affect the overall data transmission efficiency of the line.

The format bits 66 indicate whether the optional administrative header 42 is being sent, whether one or more ATM cells are being sent, or whether both or neither are being sent. As described previously, the receiver uses this information in conjunction with the transmit rate from bits 62 to identify the special symbols at the start of each ATM cell and

to determine the symbol that is the last in the message. Robust transmission of this information at the start of each message allows the transmitter to dynamically modify the message format as needed from one message to the next. Should one of the format bits be corrupted by an abnormally severe noise event, the "damage" is restricted to the

5   current message only. To operate reliably, the receiver could have a "back up" method of recognizing the end of a message such as through detecting loss of signal energy for an extended duration.

FIG. 4A is a graphical illustration representing a two (2) bit per symbol signal space constellation and the increased energy symbol of FIG. 3B. The constellation points

10   labeled "c" represent the points in a standard 2 bit per symbol constellation. For each constellation point "c" transmitted, the effect of noise can make the point appear to a receiver to have been moved with respect to where it was when it was transmitted. The dashed circle 76 surrounding constellation point 79 represents the space within which noise may move the point and still have the point reliably decoded by the receiver. The

15   point 79 appears in a different place at the decoder due to noise induced in the communications channel 16. Each of the points "c" have a space about which they can move and still be reliably decoded by the receiver.

The circle 77 encloses the area surrounding the origin of the in-phase (horizontal) and quadrature (vertical) axes of FIG. 4A about which an interval of silence (no

20   constellation point) can be moved by the same additive noise that can affect signal points. This additive noise could cause the silence to be interpreted by the decoder as one of the constellation points in a two (2) bit per symbol constellation due to the overlap of the decoding discrimination threshold circles 76 and 77. As shown, the circle 76 and the

circle 77 have sufficient overlap in region 73 so that silence can easily be interpreted as one of the signal points "c". Conversely, one of the signal points "c" could also be interpreted by the decoder as silence.

For efficient operation, it is desirable that the beginning and end of each transmission be robustly and precisely identified (to within one (1) symbol interval). The beginning and end of each transmission are preceded and followed by silence on the line. Because the most efficient constellation encoding cannot allocate signal space to silence, it is impractical to reliably discriminate silence from signal when analyzing only a single symbol. In other words, it would be undesirable for silence that occurs before a message or after a message to be interpreted as a constellation point "c", and it would be undesirable for a constellation point "c" to be interpreted as silence. As mentioned above, this is possible due to the effect of noise altering the position of the constellation signal points "c" or the position of silence.

In accordance with an aspect of the invention, the first symbol (symbol 55 of FIG. 3B) in the preamble 40 is transmitted with increased energy, thereby increasing the probability that it will be reliably detected by the decoder of the receiving device. In this manner, the beginning of each transmission is clearly and robustly delimited. The signal point "b" in FIG. 4A is an exemplar one of four (4) two (2) bit per symbol constellation points that are transmitted at an increased energy level. While other increases may provide useful, a 3dB increase is typically sufficient and does not increase the ratio of peak power to average power (PAR) of the transmitted signal. As illustrated, the signal point "b" is enclosed by dotted circle 78, within which the point "b" may move due to noise on the communication channel 16 and still be reliably decoded by the receiver. As

shown, there is no overlap between circle 78 and circle 77. Accordingly, by boosting the energy of the first symbol (symbol 55 of FIG. 3B) transmitted in a communication message (31 of Fig. 3A), there is a significantly higher probability that the boosted symbol will be reliably decoded and not be mistaken for silence. Nor will silence be

5   mistaken for this boosted energy first symbol. Preferably, the receiver places the threshold to discriminate signal from noise at one unit from the origin as shown by circle 77 in FIG. 4A.

FIG. 4B is a graphical illustration showing an exemplar grouping of constellation points representing different bit per symbol rates in accordance with an aspect of the

10   invention. For example purposes only, assuming that normal data is encoded at five (5) bits per symbol, the black constellation points, an exemplar of one of which is illustrated using reference numeral 81, represent data encoded at five (5) bits per symbol. In accordance with an aspect of the invention, all the symbols in the preamble 40 are encoded at a rate of two (2) bits per symbol and are illustrated by the four (4)

15   constellation points labeled "c" in FIG. 4B. These two (2) bit per symbol constellation points provide a higher signal-to-noise ratio (high margin) than do the normal data encoded at five (5) bits per symbol. This increased margin increases the probability that the receiver will reliably decode all the symbols in the preamble.

In accordance with another aspect of the invention, the four constellation points

20   labeled "b" in FIG. 4B represent the first symbol (symbol 55 of FIGS. 3A and 3B), which energy is boosted by 3dB. In this manner, the constellation points "b" representing the boosted symbol 55 of FIG. 3A and 3B will robustly and reliably communicate the beginning of a transmission. Circle 82 represents the maximum signal level of any

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symbols as the number of bits per symbol becomes arbitrarily large, but the average

power of the transmitted signal is the same as it is for either the five (5) bits per symbol

(81) or the two (2) bits per symbol (points "c") constellations shown. Therefore, as

illustrated by circle 82, the instantaneous power required by the boosted symbol points

5   "b" is not any higher than that used to send the normal data at any bits per symbol value.

In this manner, the boosted symbol represented by constellation points "b" can be used to

reliably indicate the start of a message without requiring a higher transmit level capability

than that needed for normal data transmission. The non-boosted two (2) bit per symbol

constellation points indicated as "c" (having a significantly higher signal-to-noise ratio

10   than that of the normal five (5) bit per symbol data) are used to transmit all symbols of

the preamble after the first symbol.

FIG. 5 is a schematic view illustrating the communication message 31 of FIG. 3A

and another aspect of the invention. Typically, it is desirable to scramble all the data bits

in a communications message using a self-synchronizing scrambler so that all points in

15   the signal constellation can be used. Unfortunately, the self-synchronizing capability of

the scrambler carries the inherent disadvantage of error propagation and extension. A

single bit in error in the received data stream is typically transformed by the self-

synchronizing descrambling process into at least 3 erroneous bits that are separated by

several bits that are not in error.

20   Typically, in switched-carrier operation, the scrambler setting (state) at the end of

one transmission is preserved and used to begin scrambling the next message. (This

enables full randomization of the encoding process so as to make full use of the available

channel bandwidth.) Similarly, in a receiving device, when descrambling, the state of the

descrambler that exists at the end of the previously received message is used to begin the

descrambling process for the next received message.   This means that the last state of

the scrambler saved after scrambling the data portion of the message would then be used

to begin scrambling the preamble bits of the next message.

5   Unfortunately, using this technique with the robust preamble 40 of the invention

can lead to error propagation from the data portion of the communication message to the

preamble 40.   Allowing errors, which are more likely due to the larger number of bits

per symbol, in the payload data to corrupt the data in the preamble due to the inherent

error extension of the descrambling process significantly reduces the robustness of the

10   preamble 40. In accordance with another aspect of the invention, a first scrambler can be

used to scramble the information contained in the preamble 40 and a second scrambler

can be used to scramble the data (*i.e.*, the information in the ATM cells 44, 45, *etc.*)

As shown in FIG. 5, line 87 indicates that a first scrambler is used to scramble the

preamble 40 of communication message 31 and also used to scramble the preamble of

15   communication message 86. Similarly, line 88 indicates that a second scrambler is used

to scramble the data portion of communication message 31 and the data portion of

communication message 86. The message to message randomizing desirable for full

usage of the available channel bandwidth can be maintained if the setting of the preamble

scrambler (to be described with respect to FIG. 8) at the end of one preamble is used to

20   begin the scrambling of the preamble of the next communication message 86. Because

errors in the preamble are considered unlikely to occur, and because the bits received at

the end of a previous preamble define the descrambler state used to descramble the next

preamble, error extension from one message preamble into the preamble is also much less

likely than in the single scrambler case.

An alternative to this that avoids the use of two scramblers is to save the state of

the preamble scrambler after scrambling the preamble as the state to use to begin

5   scrambling of the next preamble. This cab be done instead of the conventional approach

of using the state of the scrambler at the end of the message. This technique can also

prevent errors at the end of one message from corrupting the preamble of the next

transmission.

FIG. 6 is a schematic view illustrating the communication message 31 and the

10   reduced line turn around delay made possible by an aspect of the invention. In time-

domain duplex operation any periods during which no transceiver is transmitting

represent loss of available bandwidth. To make most efficient usage of a communication

line, it is desirable to minimize these periods. Some intervals of silence necessarily occur

between transmissions because the transition from silence to the first symbol of the

15   preamble is the manner in which the beginning of the next transmission is delimited. The

process by which a transceiver makes the transition from receiving to transmitting is

referred to as "line turn-around" and the time required may determine the minimum

amount of silence that can occur between messages. Various aspects of the design and

implementation of a time-domain duplex transceiver may result in increased delays in the

20   line turn-around process. For example, transmitter filters and receiver equalizers have

inherent delays. The analog-to-digital and digital-to-analog conversion process as well as

the process of transferring digital samples between the signal processor and converters

may have some inherent delays. If the signal processing is implemented in firmware

there may be delays between the arrival of received signal samples and the time the

processing can be performed. All of these factors may extend the line turn-around time to

the point that transmission efficiency is significantly reduced.

As described above with respect to FIG. 3A, communication message 31 includes

5   a specially encoded symbol 60 transmitted at a lower bit per symbol rate than that of the

normal data encoding rate. The symbol encodes an additional bit 61 that indicates

whether or not the ATM cell is the last cell in the communication message 31. If it is

indicated to the receiver at the beginning of the last ATM cell 46 that the ATM cell 46 is

the last cell in the communication message, (instead of waiting to the end of the ATM

10   cell 46) line turn around delay can be reduced. As illustrated, if a receiving device must

wait until the end of the last message to learn that the message is complete, there will be a

delay "d" between the time that the communication message 31 is received and the time

at which the transmission of communication message 91a can begin. By having advance

notification that the communication message is about to be complete, a remote DSL

15   transceiver 150 can begin transmission of the next message before reception of the

current message has been completed. By knowing the delay contributed by the factors

such as those mentioned previously, the transceiver can begin the transmission process,

indicated by communication message 91b, so as to reduce delay "d" as much as possible,

potentially reducing it to the minimum value needed for the receiver to reliably detect the

20   transition from silence to signal at the beginning of the next message.

FIG. 7 is a block diagram illustrating the control DSL transceiver 100 of FIG. 1.

Although, described with respect to control DSL transceiver 100, the following

description is equally applicable to a remote DSL transceiver 150. Control DSL

transceiver 100 includes microprocessor 101, memory 102, transmitter 115 and receiver 120 in communication via logical interface 108. A bi-directional stream of ATM cells from a DTE is communicated via line 14 to the control DSL transceiver 100. Memory 102 includes end of transmission delimiting software 106 and robust preamble software

5   104. This software resides in memory 102 and executes in microprocessor 101 in order to achieve and perform the benefits of the present invention. Transmitter 115 communicates with line interface 109 via connection 112 in order to gain access to communication channel 16. Information received on communication channel 16 is processed by line interface 109 and sent via connection 111 to receiver 120.

10   Transmitter 115 includes, among other elements that are known to those having ordinary skill in the art, encoder 200 and modulator 117. Similarly, receiver 120 includes, among other elements that have been omitted for clarity, decoder 300 and demodulator 118.

     FIG. 8 is a block diagram illustrating the encoder 200 of FIG. 7. The transmit

15   sequencer 236 commands the multiplexer 214 via connection 242 to select the first two (2) bits of the four (4) bits (62 of FIG. 3B) that define the current transmit rate from transmit rate element 206, via connection 212. This symbol is then forwarded to preamble scrambler 217, via connection 216 for scrambling, and is then forwarded via connection 218 to two (2) bit per symbol preamble encoder 219. This encoded symbol is

20   then forwarded via connection 226 to gain increase element 227 where its energy is increased by approximately 3dB and is then sent via connection 228 to multiplexer 224 and over connection 254 to modulator 117.

The next two (2) bits of the transmit rate (62 of Fig. 3B) are then scrambled and encoded in the same way. Next, the transmit sequencer 236 commands the multiplexer 214 via connection 242 to select the four (4) bits representing the requested received rate from receive rate element 204, which bits are forwarded to multiplexer 214 via connection 211. These four (4) bits are then forwarded to preamble scrambler 217 where they are scrambled, and then forwarded via connection 218 to two (2) bit per symbol preamble encoder 219 where they are encoded into a pair of symbols. These encoded symbols, are forwarded directly via connection 226 to multiplexer 224 and then forwarded via connection 254 to modulator 117.

If there are multiple remote DSL transceivers 150 and 155, then the transmit sequencer 236 commands the multiplexer 214 via connection 242 to select the two (2) bits representing the remote address from remote address element 202, which bits are then forwarded via connection 209 to multiplexer 214. These two (2) bits are then forwarded via connection 216 to preamble scrambler 217, which scrambles the bits and forwards them via connection 218 to the two (2) bit per symbol preamble encoder 219. The two (2) bit per symbol preamble encoder 219 encodes the bits and transfers the encoded symbol via connection 226 through multiplexer 224 and then via connection 254 to modulator 117.

Transmit sequencer 236 senses if an administrative header 42 and/or ATM cells 44, 45, 46 are available for transmission via connections 232 and 234, respectively, and uses this information to prepare the message format indicator which is loaded by the transmit sequencer 236 via connection 207. The transmit sequencer 236 commands the multiplexer 214 via connection 242 to select the two (2) bits representing the message

format from element 201, which bits are then forwarded via connection 208 to

multiplexer 214. These two (2) bits are then forwarded via connection 216 to preamble

scrambler 217, which scrambles the bits and forwards them via connection 218 to the two

(2) bit per symbol preamble encoder 219. The two (2) bit per symbol preamble encoder

5   219 encodes the bits and transfers the encoded symbol via connection 226 through

multiplexer 224 and then via connection 254 to modulator 117.

Next, transmission of either the administrative header 42 or the ATM cell payload

begins by transmit sequencer 236 sending a command via connection 235 to multiplexer

241 to select either the administrative header 42 via element 229 or payload data via

10   element 231. These bits are supplied through multiplexer 241 via connections 239 and

238 and are then forwarded via connection 244 to payload scrambler 246. Payload

scrambler 246 scrambles the bits and forwards them via connection 248 to N bit per

symbol data encoder 249 and N–1 bit per symbol data encoder 251. As mentioned above

with respect to FIG. 5, payload scrambler 246 may use as its initial state either the state

15   that exists at the end of scrambling the preamble (supplied via connection 247) or the

state that exists after completion of scrambling the payload portion of the previous

message. As mentioned above with respect to FIG. 3A, all the data bits are encoded at an

N bit per symbol data rate by data encoder 249 and forwarded via connection 257 to

multiplexer 224 until the first symbol containing only bits from a new ATM cell is

20   detected. This symbol is encoded at a rate of N-1 bits per symbol by N-1 bit per symbol

data encoder 251 and forwarded via connection 256 to multiplexer 224. The index for

this symbol as delivered to payload scrambler 246 is formed by selecting the first N–2

bits of the first octet of the cell and adding an additional bit (*i.e.*, bit 54 or bit 61 of FIG.

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3A) representing the state of the last cell signal 237 as selected via multiplexer 241.

When instructed by transmit sequencer 236 via connection 252, the multiplexer 224

selects the symbols from either N bit per symbol data encoder 249 or from N-1 bit per

symbol data encoder 251 and forwards these symbols via connection 254 to modulator

5   117.

Transmit sequencer 236 uses the payload bits per symbol value N received via

connection 212 to determine the number of symbols to encode for each cell and to

determine which symbol is to be encoded at the N-1 bits per symbol rate and contain the

last cell indicator bit. After completing transmission of the message, transmit sequencer

10   236 commands multiplexer 224 via connection 252 to select silence 221 via connection

222 as the input to the modulator 117.

FIG. 9 is a block diagram illustrating the decoder 300 of FIG. 7. A received

transmission stream is received in demodulator 118, where it is demodulated in

accordance with techniques known those having ordinary skill in the art. The first

15   symbol is forwarded via connection 301 to gain reduction element 302. Gain reduction

element 302 reduces the gain of the first symbol and supplies that reduced energy symbol

via connection 304 to multiplexer 306. Receive sequencer 328 sends a signal to

multiplexer 306 via connection 354 instructing multiplexer 306 to select that reduced

gain symbol and transfer it via connection 307 to two (2) bit per symbol preamble

20   decoder 308. The decoded bits from the first symbol are then sent via connection 309 to

preamble descrambler 311. Preamble descrambler 311 descrambles the first bits in the

transmission and forwards them via connection 312 to the multiplexer 314. When

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instructed by receive sequencer 328 via connection 332, the multiplexer 314 forwards

these bits via connection 324 to transmit rate element 236.

The following preamble symbols are all forwarded via connection 301 directly to

multiplexer 306, which forwards these symbols via connection 307 for decoding by two

5   (2) bit per symbol preamble decoder 308. The decoded bits are forwarded via connection

309 to preamble descrambler 311 as mentioned above. These bits are then forwarded in

order via connections 324, 321, 318 and 316 to transmit rate element 326, receive rate

element 322, remote address element 319 and message format element 317, respectively.

Next, the administrative header symbols and ATM cell data symbols that have

10   been encoded at N bits per symbol are forwarded via connection 301 to N bit per symbol

data decoder 337 and the ATM cell data symbols that have been encoded at N-1 bits per

symbol are forwarded via connection 301 to N-1 bit per symbol data decoder 339. These

symbols are decoded and the decoded bits are transferred via connections 338 and 341 to

multiplexer 342. Similarly, as mentioned above with respect to FIG. 8, receive sequencer

15   328 insures that the symbols encoded at the rate of N–1 bits per symbol are forwarded via

connection 301 to N–1 bit per symbol data decoder 339, which forwards the decoded bits

via connection 341 to multiplexer 342. As shown, the value of N, which is the bits per

symbol value used for the N bits per symbol, or N-1 bits per symbol decoding is

controlled by the just received transmit rate bits that have been stored in transmit rate

20   element 326.

At the appropriate time, receive sequencer 328 commands the multiplexer 342 via

connection 347 to forward the bits via connection 344 to payload descrambler 336. In

accordance with an aspect of the invention, the preamble descrambler 311 operates only

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on the preamble bits and the payload descrambler 336 operates only on the payload bits. As mentioned above with respect to FIG. 5, the payload descrambler may use as its initial state either the state of the preamble descrambler at the end of descrambling the preamble as supplied via connection 334 or the state of the payload descrambler at the end of

5   descrambling the payload bits of the previous message. The descrambled payload bits are then forwarded via connection 346 to multiplexer 349. When ordered by receive sequencer 328 via connection 331, the multiplexer 349 forwards the administrative header bits via connection 351 and the payload data bits via connection 352. These bits are then forwarded via logical interface 108 to microprocessor 101 for processing (FIG.

10 7). Receive sequencer 328 determines the presence or absence of the administrative header and ATM cells via the just received message format bits that have been stored in element 317 and provided to receive sequencer 328 via connection 327. When the bits for each symbol containing the last message bit are available at multiplexer 349, receive sequencer 328 directs the N-2 bits of payload data to the payload data element 356 via

15 connection 352 and receives the last cell bit via connection 329. Receive sequencer 328 uses the current bits per symbol value for payload data received via connection 324 to determine the beginning and end of each cell. Based on the message format and the value of the last cell indicator bit, receive sequencer 328 determines when the last symbol of the message has been decoded and instructs demodulator 118 (FIG. 7) to stop delivering

20 demodulated symbols.

In an alternative embodiment, the special encoding of the last cell as described above in FIG. 3A can be omitted and an "eye pattern closure test" can be used to detect the end of the message. In such a situation where it is acceptable to lose the advanced

notification of the end of the transmission, beneficial alternative uses for the special

encoding of the first bits of each cell are possible. For example, this special encoding as

described above with respect to FIG. 3A wherein N–2 bits are encoded for the first full

bytes of each cell, can be used to indicate whether or not the ATM cell header (e.g., ATM

5   header 47 of FIG. 2B) is present. This can be useful in the situation in which a string of

ATM cells have exactly the same header. This can happen, for example, for ATM

adaptation layer 5 (AAL5) cells that carry data from a single protocol data unit (PDU) if

no other cells have been interleaved. The single extra bit (bit 61 of FIG. 3A) provided by

the encoding described above with respect to FIG. 3A, can be used to indicate whether or

10   not the following cell contains a header. If the bit 61 indicates that there is no header, the

receiver copies the last header received ahead of the payload octets of this next cell before

forwarding it to the ATM layer. Advantageously, this reduces the approximate 10 percent

overhead imposed by the five (5) octet header (47 of FIG. 2B).

It should be emphasized that the above-described embodiments of the present

15   invention, particularly any "preferred" embodiments, are merely possible examples of

implementations, merely set forth for a clear understanding of the principles of the

invention. Many variations and modifications may be made to the above-described

embodiment(s) of the invention without departing substantially from the spirit and

principles of the invention. For example, the robust preamble and transmission

20   delimiting system and method are applicable to all switched-carrier transmission

methodologies in which it is desirable to reliably convey channel establishment

information and reliably delimit the beginning and end of each communication message.

All such modifications and variations are intended to be included herein within the scope

5   of the present invention.